New Higgs interactions and recent data from the LHC and the Tevatron

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The main questions

- Is the particle discovered by CMS and ATLAS, the SM Higgs?

- Do the present data allow any scope for BSM effects?

What's new in our work

- 7-parameter global fit presented.
- Different coupling modifications to W and Z bosons allowed.
- Different coupling modifications to u-type and d-type quarks allowed.
- Arbitrary phase in the top-quark coupling allowed.
- Invisible decay width of Higgs allowed.
- Additional states allowed in Hgg and $H\gamma\gamma$ couplings.

Parametrization of new physics effects

- Fermion Couplings : Classifying all $T_3 = +1/2$ fermions as u and all $T_3 = -1/2$ fermions as d, we assume

$$\mathcal{L}_{H\bar{u}u} = e^{i\delta}\alpha_u \frac{m_u}{v} H\bar{u}u$$
$$\mathcal{L}_{H\bar{d}d} = \alpha_d \frac{m_d}{v} H\bar{d}d$$

- Gauge boson pair couplings : We parametrize the interactions of the observed scalar to a pair of weak gauge bosons as

$$\mathcal{L}_{HWW} = \beta_W \frac{2m_W^2}{v} HW_\mu^+ W^{\mu -}$$
$$\mathcal{L}_{HZZ} = \beta_Z \frac{m_Z^2}{v} HZ_\mu Z^\mu$$

Parametrization of new physics effects

- Effective gluon-gluon and photon-photon couplings : We parametrize the gluon-gluon-Higgs and Higgs-photon-photon amplitudes as follows :

$$\mathcal{L}_{gg} = -x_g f(\alpha_u) \frac{\alpha_s}{12\pi v} H G^a_{\mu\nu} G^{a\mu\nu}$$
$$\mathcal{L}_{\gamma\gamma} = -x_\gamma g(\alpha_u, \alpha_d, \beta_W, \delta) \frac{\alpha_{em}}{8\pi v} H F_{\mu\nu} F^{\mu\nu}$$

- Invisible width : Earlier studies have given different conclusions about a possible invisible decay width of Higgs. Here we parametrize it as :

$$\Gamma_{inv} = \frac{\epsilon}{1-\epsilon} \sum \Gamma_{vis}$$

where ϵ is the invisible branching fraction.

Methodology

- Experimental collaborations have reported various observed signal strengths in the i^{th} channel in terms of $\hat{\mu}_i = \sigma_i^{obs}/\sigma_i^{SM}$.
  - σ_i^{obs} : observed signal cross-section for a particular Higgs mass.
  - σ_i^{SM} : signal cross-section for an SM Higgs with the same mass.

- We calculate μ_i for various points in the space spanned by the parameters.

- We can express μ_i as

$$\mu_i = R_i^{prod} \times R_i^{decay}/R^{width}$$

- We consider latest results from CMS and ATLAS and available results from Tevatron.

- The following decay channels are considered in our analysis : $\gamma\gamma$(inclusive), $ZZ^* \to 4\ell$, $WW^* \to \ell\ell\nu\nu$, $\tau^+\tau^-$, $b\bar{b}$, $\gamma\gamma jj$.

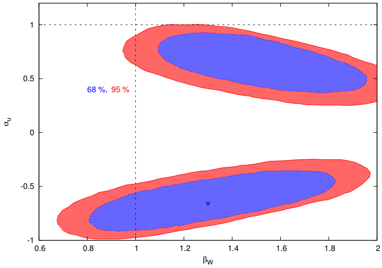
Best-fit values of parameters

χ^2 analysis was performed to obtain the best-fit values of the different parameters.

Case	β_W	β_Z	α_u	α_d	x_g	x_γ	ϵ	δ
A	1.3	1.4	-0.66	-1.2	1.6	1.0	0.4	0*
B	1.15	1.15	-1.48	1.04	0.6	0.9	0.1	1.0
C	1.07	1.07	-0.27	0.97	3.1	1.0	0.02	0*

Table: Best-fit values of the various parameters in the three cases considered. In cases A and C, δ has been fixed at 0 (indicated with a '$*$'). In cases B and C, the relation $\beta_W = \beta_Z$ has been imposed, and their values have been restricted within precision constraints.

Contour Plots (Case A)



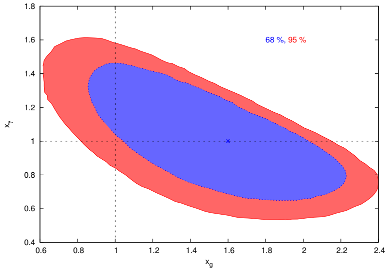


Figure: Two-dimensional contour plots for 68% and 95% confidence intervals, for case A, with rest of the parameters fixed at their best-fit values. The best-fit point is also marked separately by a '$*$'. In this case δ has been fixed at 0, whereas $0 \leq \beta_W, \beta_Z \leq 2.0$, and $\beta_W \neq \beta_Z$.

Contour Plots (Case B)

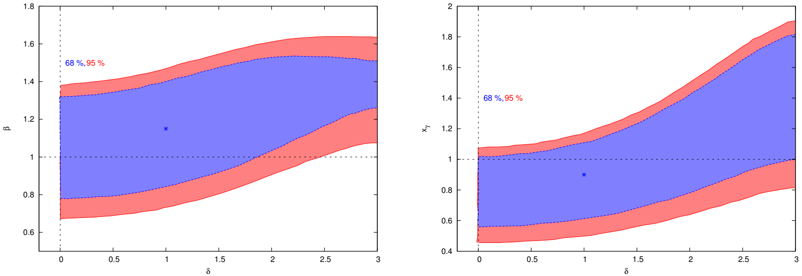


Figure: Two-dimensional contour plots for 68% and 95% confidence intervals, for case B, with rest of the parameters fixed at their best-fit values. The best-fit point is also marked separately by a '$*$'. In this case δ has been varied in the range $\{0, \pi\}$, whereas $0.92 \leq \beta \leq 1.18$, with $\beta \equiv \beta_W = \beta_Z$.

χ^2 vs ϵ plots

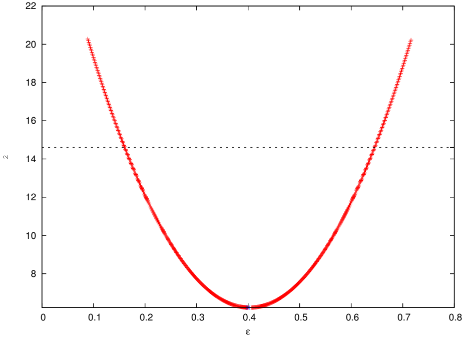


Figure: Variation of the χ^2 function with the invisible branching fraction of H (ϵ) in case A ($\delta = 0$ and $\beta_W \neq \beta_Z$).

χ^2 vs δ plot

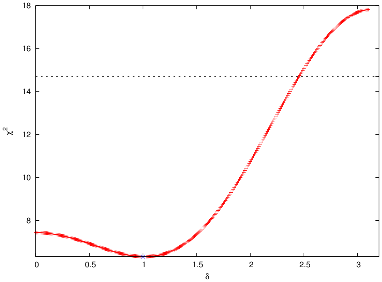


Figure: Variation of the χ^2 function with the phase in the up-type quark Yukawa coupling, δ, in case B. In this case δ has been varied in the range $\{0, \pi\}$, whereas $0.92 \leq \beta \leq 1.18$, with $\beta \equiv \beta_W = \beta_Z$.

Conclusions

- Fermiophobic Higgs is by and large disfavoured.
- Non-trivial phase in top-quark coupling play an important role. Can be as large as $\frac{4}{5}\pi$ radians at 68% confidence interval.
- Hint of relative sign between α_u and β_W.
- Hint of an invisible decay width of Higgs. Can be as large as 60% (Case A) and 45% (Case B) at 68% confidence interval.
- Given the present data, substantial departure from SM couplings are allowed.

References

Some of the recent works in similar spirit :

- A. Azatov, R. Contino and J. Galloway, JHEP **1204**, 127 (2012). A. Azatov, R. Contino, D. Del Re, J. Galloway, M. Grassi and S. Rahatlou, arXiv:1204.4817 [hep-ph].
- J.R. Espinosa, C. Grojean, M. Muhlleitner and M. Trott, arXiv:1202.3697 [hep-ph]; J.R. Espinosa, M. Muhlleitner, C. Grojean and M. Trott, arXiv:1205.6790 [hep-ph]; J. R. Espinosa, C. Grojean, M. Muhlleitner and M. Trott, arXiv:1207.1717 [hep-ph];
- P. P. Giardino, K. Kannike, M. Raidal and A. Strumia, arXiv:1203.4254 [hep-ph]; P.P. Giardino, K. Kannike, M. Raidal and A. Strumia, arXiv:1207.1347 [hep-ph];
- M. Farina, C. Grojean, E. Salvioni, arXiv:1205.0011 [hep-ph];
- J. Ellis and T. You, JHEP **1206** (2012) 140; J. Ellis and T. You, arXiv:1207.1693 [hep-ph];

Marginalisation - Backup

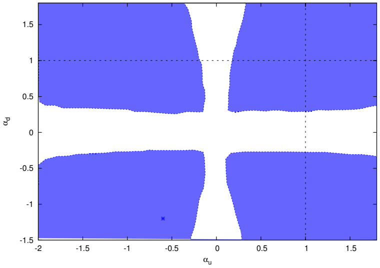


Figure: Two-dimensional marginalised contour plots for 68% confidence intervals, for case A. The best-fit point is also marked separately by a '$*$'. In this case δ has been fixed at 0, whereas $0 \leq \beta_W, \beta_Z \leq 2.0$, and $\beta_W \neq \beta_Z$. This is based on the data published on 4th July and before.